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Multifunctional $GdVO_4$:Eu Core-Shell Nanoparticles Containing ^{225}Ac for Targeted Alpha Therapy and Molecular Imaging*

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Electronic Supplementary Information

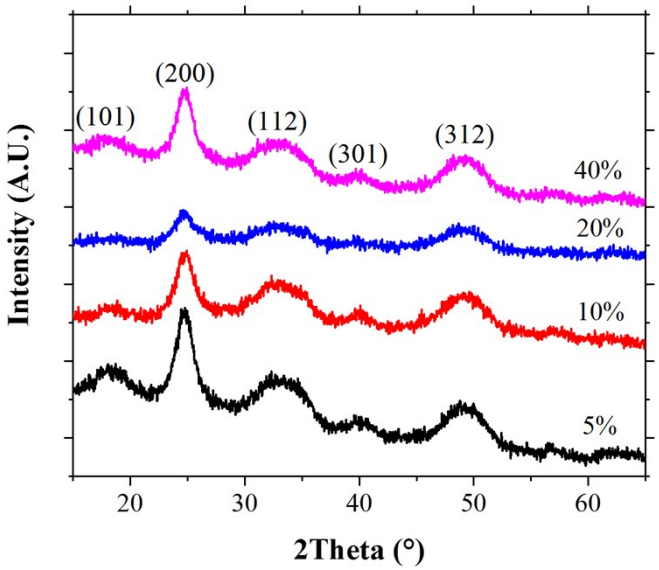

Fig. S.1 Diffraction patterns of $Gd_{(1-x)}Eu_xVO_4$ core NPs

Table S.1 Summary of crystallite size measured for $Gd_{(1-x)}Eu_xVO_4$ core NPs

Sample	Crystallite size (nm)
$Gd_{0.95}Eu_{0.05}VO_4$	4.5
$Gd_{0.9}Eu_{0.1}VO_4$	4.4
$Gd_{0.8}Eu_{0.2}VO_4$	4.7
$Gd_{0.6}Eu_{0.4}VO_4$	4.7

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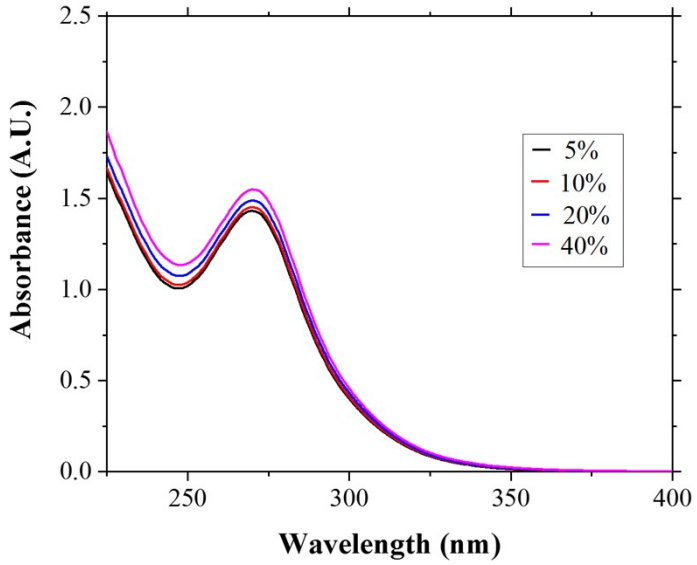

Fig. S.2 Absorption spectra of $Gd_{(1-x)}Eu_xVO_4$ core NPs

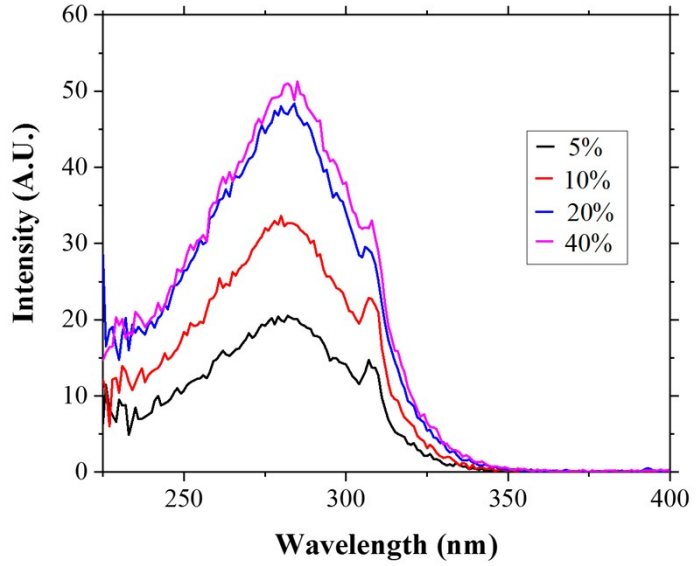

Fig. S.3 Excitation spectra of $Gd_{(1-x)}Eu_xVO_4$ core NPs

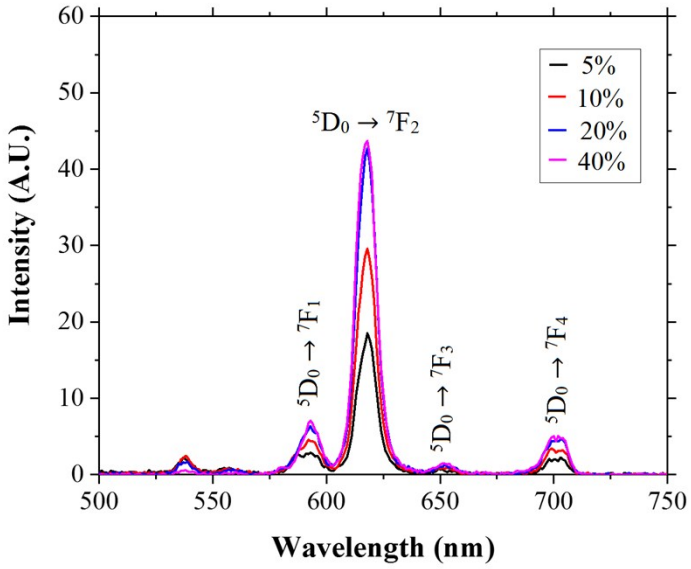

Fig. S.4 Emission spectra of $Gd_{(1-x)}Eu_xVO_4$ core NPs

Table S.2 Lanthanide weight percentage based on EDS results for $Gd_{(1-x)}Eu_xVO_4$ core NPs

	Weight percentage	
Sample	**Eu (%)**	**Gd (%)**
$Gd_{0.95}Eu_{0.05}VO_4$	5.6	94.4
$Gd_{0.9}Eu_{0.1}VO_4$	10.6	89.4
$Gd_{0.8}Eu_{0.2}VO_4$	20.9	79.1
$Gd_{0.6}Eu_{0.4}VO_4$	40.4	59.6

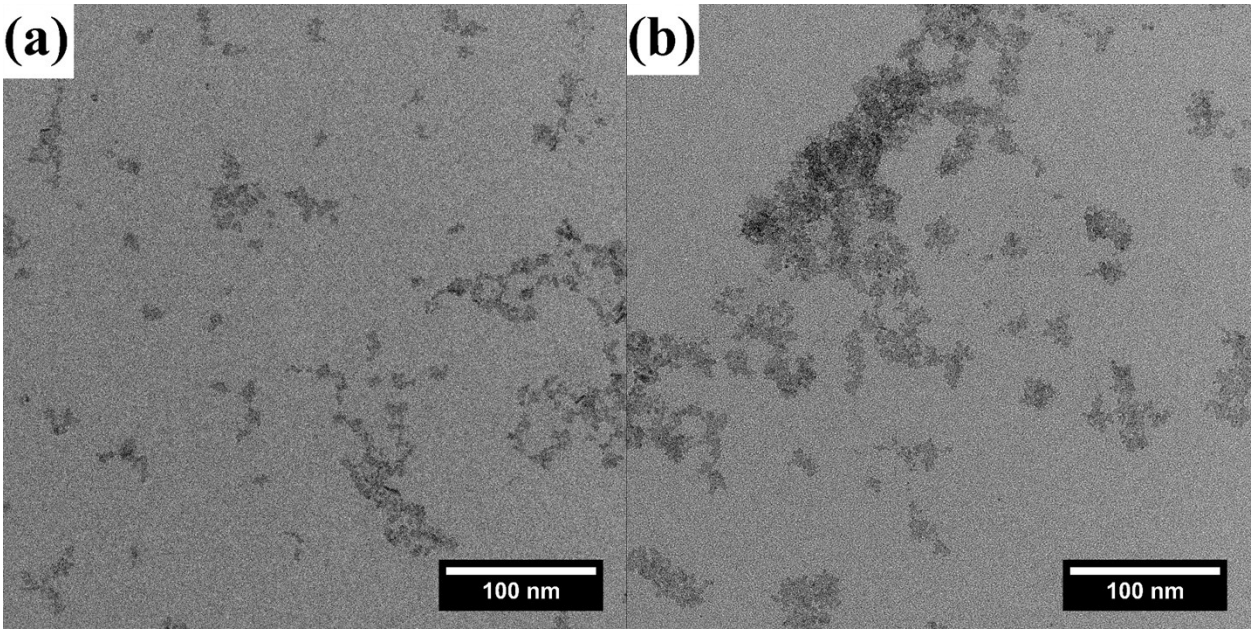

Fig. S.5 TEM images of $Gd_{0.8}Eu_{0.2}VO_4$ (a) core and (b) core + 2 shells NPs

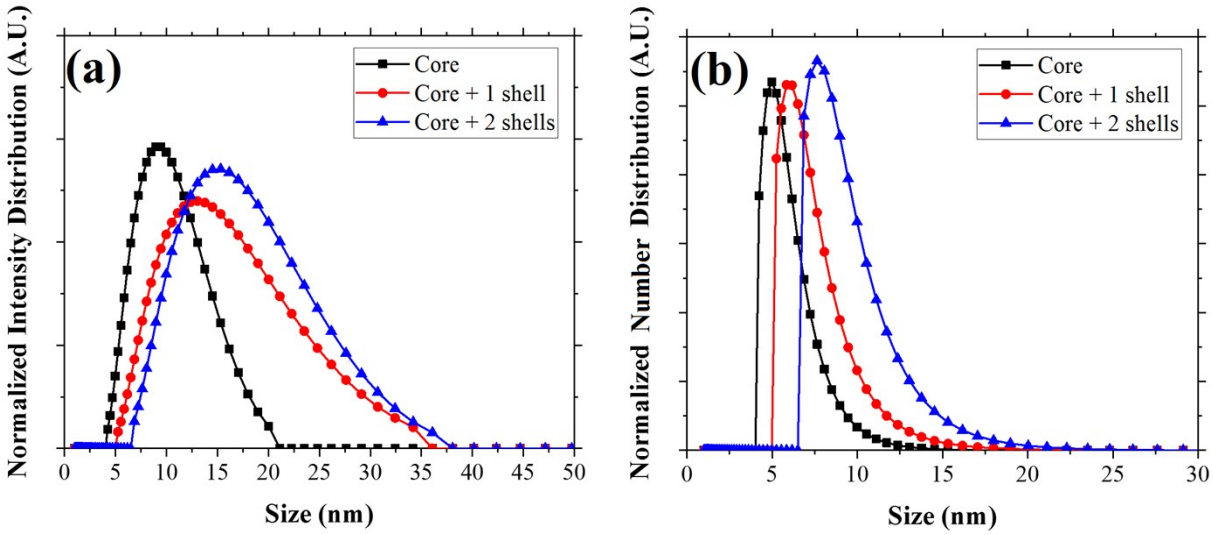

Fig. S.6 (a) Intensity and (b) number particle size distributions of $Gd_{0.8}Eu_{0.2}VO_4$ core and core-shell NPs

Table S.3 Magnetic susceptibility of $Gd_{0.8}Eu_{0.2}VO_4$ core and core-shell NPs

Sample	Magnetic Susceptibility ($\times 10^{-6}$ emu Oe^{-1} g^{-1})
Core	56.4
Core + 1 shell	56.3
Core + 2 shells	56.0

Table S.4 Lanthanide weight and atomic percentage of $Gd_{0.8}Eu_{0.2}VO_4$ core and core-shell NPs

	Weight percentage		Atomic percentage	
Sample	Eu (%)	Gd (%)	Eu (%)	Gd (%)
Core	78.0	22.0	77.3	22.7
Core + 1 shell	78.0	22.0	77.3	22.7
Core + 2 shells	77.9	22.1	77.3	22.7

Table S.5 Absolute quantum yield of $Gd_{(1-x)}Eu_xVO_4$ core NPs

Sample	Absolute quantum yield (%)
$Gd_{0.95}Eu_{0.05}VO_4$	29.4
$Gd_{0.9}Eu_{0.1}VO_4$	25.7
$Gd_{0.8}Eu_{0.2}VO_4$	23.5
$Gd_{0.6}Eu_{0.4}VO_4$	22.6

Table S.6 Absolute quantum yield of $Gd_{0.8}Eu_{0.2}VO_4$ core-shell NPs

Sample	Absolute quantum yield (%)
Core	22.8
Core + 1 shell	18.5
Core + 2 shells	14.0

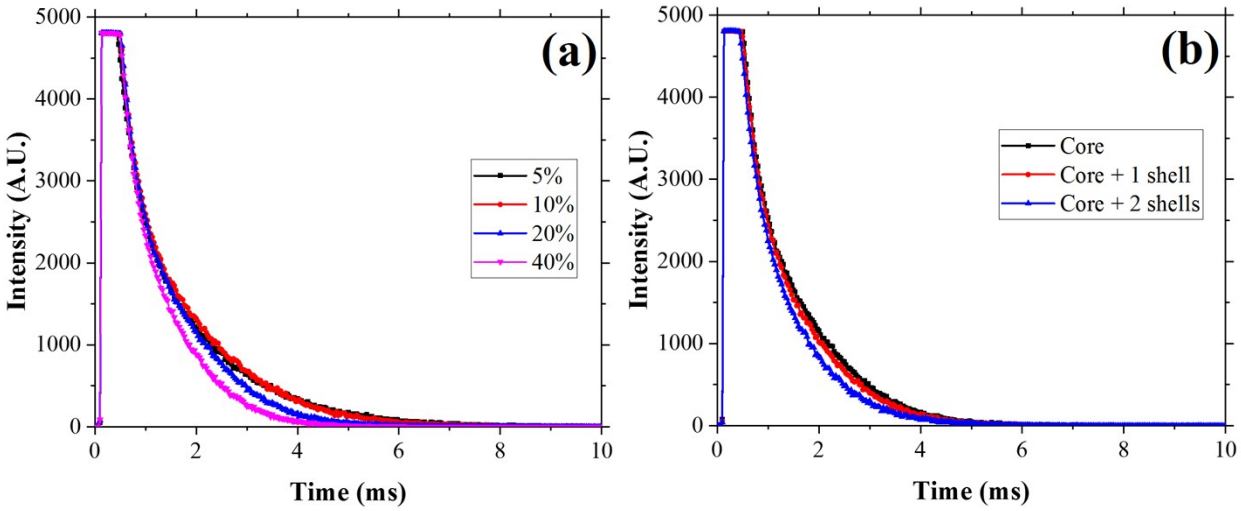

Fig. S.7 Time-resolved luminescence decay curves of (a) $Gd_{(1-x)}Eu_xVO_4$ and (b) $Gd_{0.8}Eu_{0.2}VO_4$ core-shell NPs

Table S.7 Luminescence decay lifetimes of $Gd_{(1-x)}Eu_xVO_4$ and $Gd_{0.8}Eu_{0.2}VO_4$ core-shell NPs fitted using a biexponential function [$I = A_1 \exp(-t/\tau_1) + A_2 \exp(-t/\tau_2) + I_0$]

Sample	A_1	τ_1 (µs)	A_2	τ_2 (µs)	R^2	τ_{ave} (ms)
$Gd_{0.95}Eu_{0.05}VO_4$	5935.4 ± 124.8	351.0 ± 9.6	4025.1 ± 60.2	1637.8 ± 17.5	0.9994	1.33
$Gd_{0.9}Eu_{0.1}VO_4$	5406.7 ± 227.6	363.5 ± 22.0	4387.8 ± 133.9	1607.5 ± 33.6	0.9979	1.34
$Gd_{0.8}Eu_{0.2}VO_4$	4339.2 ± 363.5	316.7 ± 35.8	5486.6 ± 210.1	1246.2 ± 27.3	0.9974	1.09
$Gd_{0.6}Eu_{0.4}VO_4$	3800.8 ± 318.9	310.9 ± 45.2	6158.2 ± 320.4	999.1 ± 24.1	0.99791	0.89
Core	4339.2 ± 363.5	316.7 ± 35.8	5486.6 ± 210.1	1246.2 ± 27.3	0.9974	1.09
Core + 1 shell	4266.8 ± 269.8	328.1 ± 33.1	5501.8 ± 219.5	1173.2 ± 24.6	0.99814	1.02
Core + 2 shells	4363.9 ± 240.5	288.3 ± 21.9	5887.1 ± 157.0	1008.4 ± 13.3	0.99922	0.88

Table S.8 Luminescence decay lifetimes of $Gd_{(1-x)}Eu_xVO_4$ and $Gd_{0.8}Eu_{0.2}VO_4$ core-shell NPs fitted using a exponential function [$I = A_1 \exp(-t/\tau_1) + I_0$]

Sample	A_1	τ_1 (µs)	R^2
$Gd_{0.95}Eu_{0.05}VO_4$	6260.21 ± 59.68	1166.61 ± 13.55	0.99138
$Gd_{0.9}Eu_{0.1}VO_4$	6509.98 ± 60.53	1194.31 ± 13.71	0.99163
$Gd_{0.8}Eu_{0.2}VO_4$	7083.28 ± 53.91	1051.62 ± 9.20	0.99497
$Gd_{0.6}Eu_{0.4}VO_4$	7808.46 ± 52.47	872.27 ± 6.09	0.99669
Core	7083.28 ± 53.91	1051.62 ± 9.20	0.99497
Core + 1 shell	7273.26 ± 51.17	984.83 ± 7.68	0.99595
Core + 2 shells	7559.82 ± 43.40	869.41 ± 5.18	0.99759

Table S.9 Bi ions concentration and relative retention of Bi by core to core + 2 shells NPs

Dialysis Period	Bi ion concentration in dialysate (µg/mL)		Relative Retention of Bi by Core to Core + 2 shells NPs
	Core	Core + 2 shells	
30 min	0.41 ± 0.31	0.47 ± 0.32	1.1 ± 1.0
1 h	0.44 ± 0.30	0.59 ± 0.30	1.3 ± 0.9
2 h	0.51 ± 0.29	0.68 ± 0.30	1.3 ± 0.7
4 h	0.51 ± 0.30	0.72 ± 0.30	1.4 ± 0.7
24 h	0.50 ± 0.29	0.70 ± 0.29	1.4 ± 0.7
47 h	0.45 ± 0.31	0.79 ± 0.32	1.8 ± 0.8